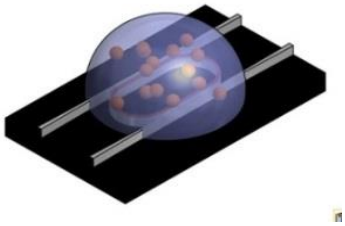
Offer - Thesis : Nano-integrated resonant light probes for dynamic diagnostics in soft-process bio-metrology



Director of Thesis : Bruno Bêche, Pr. et Véronique Vié, Dr. HDR

▪ **Keywords** : Photonics and sensors, integrated probe light for ultra-fine bio-metrology and study of soft matter processes and biology, phase transition measurements, molecular association / dissociation time measurements of interacting lipids, structural transition supramolecular assemblies, measurement of changes in the rheological properties of supramolecular assemblies.

▪ Context, Scientific positioning

Optical microcavities or microresonators have been most generic components, for the last decade, so as to design and fabricate integrated photonic devices leading to the development of numerous applications in science. They include as much fundamental physics studies as the researches for engineering telecommunications, biophysics, biochemical and biology. To a certain extent, as such resonant quantifications met in physics are due to a geometric recirculation of the light (by way of whispering gallery modes), they increase both the field and merit of integrated photonics regarding a significant set of optical versatile applications together with sensors for metrology with platform analysis and relevant detection procedure. In an overall landscape of technologies, resonators based on organic materials exhibit a lot of advantages due to the well-established printing or photolithographic technologies, the versatility of the polymer properties with functionalization and the possibility to be shaped starting from a liquid photoresist material with fluidic thin layer specific deposition principles. Globally, the reasons of the progress in this research field are various and easily justified with the potential of numerous available materials, the simplicity of the relevant processes, the specific methods and measurements protocols and low costs of the entailed devices. More recently, organic materials based resonators have received intensive attention in metrology and sensing environmental applications, biology, medical and healthcare diagnostics, food quality control and security. Such photonics sensors relying on resonators have become the subject of comprehensive research with sizeable developments of enhanced sensing platforms devoted to the label-free detection of a wide variety of chemical, biochemical, biological agents and biomedical materials.

▪ Objectives of the thesis

The need to develop integrated nano-instrumentation for high-sensitivity detection is a major and crucial challenge for the biomedical, health, rapid testing and diagnostics fields in analytical laboratories. Nowadays, only few companies are working on the development of integrated bio-nano-

sensors dedicated to the detection and measurement of interactive processes within soft matter (biological or not). The thesis subject and associated project relate to the fields of nanosciences and nanobiotechnologies. It forms part of an integrated biophotonics on organic materials for fine metrology relating to processes and to certain mechanisms of soft matter and biology. These high sensitivity integrated resonant light probes are obtained by the control of hybrid processes in nano-bio-technologies for the realization of chips (with deep UV lithography on organic substrates, thermal control necessary for the biological and cellular stability of the techniques of soft matter and biophysics). The principle of relevant nano-devices and sensors is based on the control and manipulation of photons via their quantified optical resonant modes for the dynamic detection of the interaction time between light and a given soft process material: then, are involved; phase transition measurements in soft matter and biology, measurement of changes in the rheological properties of supramolecular assemblies, measurements of the association / dissociation times of biomolecules with cellular membranes in biology (lipid / protein interaction), using the concept of nano-probes of resonant light.

As an example, sphingomyelin (SPH) is a type of sphingolipid found in animal cell membranes. It is especially prominent in myelin, a membranous sheath that surrounds and insulates the axons of numerous neurons. In humans, SPH represents 85% of all sphingolipids, with higher concentrations found in nerve tissues, red blood cells, and the ocular lenses… Such a plasma membrane component participates in many signaling pathways. Its metabolism entails many products that play significant roles in the cell. A first part of the thesis work is aimed at exploring and investigating low-cost and easily reproducible polymeric biophotonic sensors (integrated on chip-devices) which are devoted to perform efficient crucial lipid first order phase transition detection based on a gel-liquid state-change. Relevant lipids studied in this part of the subject will play a crucial role in the membrane of cells.

A second part of the thesis will be devoted to the dynamic measurement of tuning macroscopy rheology of supra-molecular assemblies and organization used in pharmacology. A large variety of self-assembled structures as spherical micelles, flat lamellar structured, bi-layer vesicle, elongated tubular structures may be considered as solutions… Such self-assembled structures can transform from one morphology into another one under specific stimuli as temperature, light, pH… This part of the thesis work will encompass the global study of thermo- and light-responsive properties of such supra-molecular structures by way of the integrated resonant probe-light principle.

▪ Experimental means and collaborations

The candidate will benefit from the whole experimental park of the Institute of Physics of Rennes (IPR CNRS) and their departments, the NanoRennes Technology Center within the Institute of Electronics and Telecommunications of Rennes (IETR CNRS) and the know-how of the STLO-INRA of the Agro-campus West of Rennes.

▪ Expertise and Complementarity of supervisors

Bruno Bêche, Professor at the Institute of Physics of Rennes IPR CNRS / University of Rennes 1. Honorary Member of the 'Institut Universitaire de France' / IUF Paris.
bruno.beche@univ-rennes1.fr ; **http://blogperso.univ-rennes1.fr/bruno.beche/**

with, Arnaud St-Jalmes, Director at CNRS plus Véronique Vié, Hervé Lhermite and Claire Bourlieu…

▪ Some bibliographical references of the group:

• B. Bêche, A. Potel, J. Barbe, V. Vié, J. Zyss, C. Godet, N. Huby, D. Pluchon E. Gaviot, 'Resonant coupling into hybrid 3D micro-resonator devices on organic/biomolecular film/glass photonic structures', *Opt. Comm.,* **2010**, vol. 283, n°1, pp. 164-168.
• D. Duval, H. Lhermite, C. Godet, N. Huby, B. Bêche, 'First developments of integrated photonics on UV 210', *Institute of Physics Publishing IoP - J. Opt. A: Pure Appl.*, 2010, vol. 12, n°5, pp. 055501-055507.
• D. Pluchon, N. Huby, H. Lhermite, D. Duval, B. Bêche, 'Fabrication and resonant optical coupling of various 2D micro-resonators structures on UV210 polymer', *Institute of Physics Publishing IoP - J. Micromech. Microeng.,* **2012,** vol. 22, pp. 085016-085024.
• D. Pluchon, N. Huby, L. Frein, A. Moréac, P. Panizza, B. Bêche, 'Flexible Beam-Waist Technique for Whispering Gallery Modes Excitation in Polymeric 3D Micro-Resonators', *Opt. Int. J. Light Electron. Opt,* **2013,** vol. 124, pp. 2085-2088.
• D. Pluchon, N. Huby, P. Panizza, B. Bêche, **'**AFM analysis of 3D optical microresonators surfaces : a correlation to Q-factors values', *Opt. Photon. J*.., **2013,** vol. 3, (4) pp. 291-295.
• A-L. Fameau, A. St-Jalmes, 'Yielding and flow of solutions of thermoresponsive surfactant tubes: tuning macroscopy rheology by supramolecular assemblies', *Soft Matter, Royal Society of Chemistry*, **2014**, vol. 10, (20), pp.3622-3632.
• R. Castro Beltran, N. Huby, G. Loas, H. Lhermite, D. Pluchon, B. Bêche, 'Improvement of efficient coupling and optical resonances by using taper-waveguides coupled to cascade of UV210 polymer micro-resonators', *IoP - J. Micromech. Microeng.,* **2014,** vol. 24, pp. 125006-125013.
• R. Castro Beltran, N. Huby, V. Vié, H. Lhermite, L. Camberlein, E. Gaviot, B. Bêche, 'A laterally coupled UV210 polymer racetrack micro-resonator for thermal tunability and glucose sensing capability', *Adv. Dev. Mat.,* **2015,** vol. 1, n°3, pp. 80-87.
• Q. Li, V. Vié, H. Lhermite, E. Gaviot, A. Moréac, D. Morineau, C. Bourlieu, D. Dupont, S. Beaufils, B. Bêche, 'Sphingomyelin Lipid Gel/Fluid Phase Transition detection with quasi-athermal Racetrack Polymer Resonators', **2017**, submitted.